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AUTHOR Nowaczyk, Ronald H.
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ABSTRACT

Research directed toward a better understanding of the computer user/computer machine relationship has increased in recent years. To identify what factors may predict success in computer programming, 286 college students from three computer classes (160 from introductory programming; 60 from Cobol programming; and 66 from senior level programming) completed a 30-minute question answering and problem solving test. Cognitive factors (past academic performance and problem solving ability) were assessed through self-reported grades and seven math and logic problems. Personality factors (computer anxiety and locus of control) were assessed by items from the Fennema and Sherman Mathematics Attitude Scale and a modified internal/external (I-E) scale of personal locus of control. An analysis of the results showed that past academic performance in mathematics and English courses, amount of previous computer experience, expected grade in the course, and performance on selected logic and algebraic-word problems were significantly correlated to course performance. Neither of the personality factors predicted performance, since few students showed any computer anxiety and most showed an internal locus of control. (BL)

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COGNITIVE SKILLS NEEDED IN COMPUTER PROGRAMMING

Ronald H. Nowaczyk

Clemson University

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ABSTRACT

This is a report of a study identifying factors that predict success of college students in Introductory-level computer programming courses. These factors include past academic performance, personality factors, and performance in problem solving. Students (N = 286) from Introductory programming (WATFIV), Cobol, and Advanced programming courses completed a test form that included questions and problems related to these factors. The form, administered during the first week of the semester, took 30 minutes to complete. Regression analyses revealed that the form accounted for a significant proportion of the variability of final grades for the Introductory and Advanced programming courses. Past academic performance in mathematics and English courses, amount of previous computer experience, expected grade in the course, and performance on selected logic and algebraic-word problems were significantly related to course performance. The test form was unable to differentiate those students who dropped the course during the semester from those who successfully completed the course.

COGNITIVE SKILLS NEEDED IN COMPUTER PROGRAMMING

In recent years there has been an increase in research directed toward a better understanding of the computer user/computer machine relationship (cf. Shneiderman, 1980). Some of this research deals with understanding the programming process. Several studies have attempted to identify factors that will predict an individual's ability as a computer programmer. Leeper and Silver (1982) and Petersen and Howe (1979) have investigated the relationship between past academic performance and performance in a college computer programming course. While they have met with some success, another has not (Mazlack, 1980).

Others have looked at problem solving ability and computer course performance. Cheney (1980) has identified two types of problem-solvers, analytic- and heuristic-decision makers, and reported that the analytic-decision makers are better programmers. Kurtz (1980) classified students in his own course as to their level of abstract reasoning and reported some success in predicting course performance.

This study incorporates both previously studied factors, past academic performance and problem-solving ability, along with two personality factors, computer anxiety and personal locus of control, in order to better understand the relationship between these factors and computer course performance. The personality factors were included in response to Schneiderman's (1980) call for research on personality factors. A larger and more diverse sample of students (in terms of course enroll-

ment) was used in this study than had been in previously published studies.

Method

Subjects

A total of 301 students enrolled at Clemson University completed the test form. Of these students, the data from 15 students were discarded because the students were either auditing the course or failed to provide the needed information for identifying them later. 160 students (82 males and 78 females) were enrolled in one of three sections of an Introductory programming (WATFIV) course, 60 (29 males and 31 females) were enrolled in one of two sections of a Cobol programming course, and 66 (41 males and 25 females) were enrolled in one of two advanced-level (senior-level) programming courses.

Test form and procedure

The test form consisted of three sections and was a revision of a form that had been used the previous summer session. The first section asked for background information including age, sex, year in school, major, previous computer experience, expected grade in the course, and past academic performance in English, Foreign Language, and Mathematics courses. The second section of the form contained 27 statements, 18 of which were reworded statements from the Fennema and Sherman Mathematics Attitude Scale (Fennema & Sherman, 1976) and 9 were statements selected from a modified I-E scale of personal locus of control (Collins, 1974). Students rated their agreement with each statement using a 6-point Li-

kert scale. The third section contained seven problems distributed across four pages. The order of presentation of these pages was balanced across students. In addition to the problems listed in Table 1, another math-relationship problem from Silver (1981) was included. Also, a four-card selection problem (Wason & Johnson-Laird, 1972) was included. This required the student to apply the rule "If an envelope is sealed then it must have a 20¢ stamp on it" to a diagram of four envelopes differing in whether they were face up (with 15¢ or 20¢ stamp) or face down (sealed or unsealed). The Loch Ness problem was selected from Gardner (1978) and the river-crossing problem was selected from Greeno (1978). Three positive and five negative instances of the concept for the attribute identification problem were also included on the test form.

insert table 1 about here

The test form was administered during a class meeting of the first week of the semester. Students were allowed 10 minutes to complete the first two sections and 5 minutes on each of the four problem pages.

Results

Regression analyses were conducted for each course with final course grade as the criterion variable and the various factors and problems on the test form as predictor variables. Only students who received final grades were included in these analyses. In the Introductory-level courses, the test form accounted for a significant ($p < .05$) proportion of variability in final grades, $R^2 = .45$. Significant factors included previous Math and English course performance and amount of computer ex-

perience. The test form also accounted for a significant proportion of the grade variability in the Advanced-level courses, R^2 = .42. The only significant factor was expected grade. While the test form accounted for a large proportion of the grade variability in the Cobol course, R^2 = .81, it was nonsignificant. This was the result of an unusually low completion rate in the course, 36% versus 78% in the other courses. The Cobol course has traditionally had a large drop rate and has a different population of students (business-related majors) than the other computer courses.

An analysis was also performed on the number of problems solved for the students by course and grade received. The mean and standard deviations are presented in Table 2. Seven was the maximum number of correct problems that could be solved. A 3 X 6 unequal-n analysis of variance was performed. Significant differences were found for course, F (2, 268) = 6.98, $p < .05$, and for grade, F (5, 268) = 4.11, $p < .05$. The interaction was not significant. A series of Newman-Keuls analyses revealed that the Advanced students solved more problems than the other students, and that the 'A' students solved more problems than the 'D', 'F', and 'Drop' students. Notice that these differences are most obvious for the Introductory and Cobol students. Unfortunately, there appears to be no real difference in performance between the 'Drop' students and the students who successfully completed the course ('A, B, and C' students). Peformance among the Advanced students was more uniform across the different grade groups. A series of secondary analyses looking at the relationship between grade and problem performance for each problem was performed. The analyses revealed significant relationships

between grade and problem performance for the Loch Ness, r_{pb} = .20, River-crossing, r_{pb} = .17, and the four-card selection (envelope) problems, r_{pb} = .18 ($p < .05$ in all cases).

insert table 2 about here

Discussion

The findings of this study support previous research investigating factors related to computer course performance. Past academic performance is a valid predictor of course performance as is problem-solving ability. The fact that the personality factors included in this study did not predict performance might be explained by noting that very few students showed any computer anxiety and most were internalizers (with regard to personal locus of control). This study furthered research in the area in at least two ways. First, a larger and more diverse sample was used in this study than in previous work. The fact that the advanced students solved more problems than the other students can be viewed as validating evidence for the position that problem-solving ability is an important component in programming and the computer-science curriculum. The finding that problem-solving performance was more homogeneous across grade levels for the advanced students suggests that performance in these courses is based on factors other than problem-solving ability.

Second, the test form used in the present study was much shorter than that used in previous studies. Ideally for a test form to be used in predicting course performance, it should be as short as possible to facilitate ease in adminstering and minimize loss of instructional time.

This form took only 30 minutes to administer, whereas Cheney (1980) and and Kurtz (1980) reported completion times of 90 minutes or more.

Future research must be directed at refining the test form and identifying the critical problems to be included. The finding that algebraic-word problems, logic problems, and transformation problems significantly contribute to course performance is an important step in that direction. The ability to solve problems appears to be an important component in the programming process and may be critical for the novice programmer who is learning how to integrate 'semantic' skills, such as problem- solving ability, with 'syntactic' skills, writing computer code.

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TABLE 1

PROBLEMS USED ON THE TEST FORM

LOCH NESS PROBLEM - IF THE TOTAL LENGTH OF THE LOCH NESS MONSTER IS 20 YARDS AND HALF OF ITS OWN LENGTH, HOW LONG IS IT?

BASEBALL CARD PROBLEM - WE KNOW THAT TOM AND BILL HAVE A TOTAL OF 24 BASEBALL CARDS BETWEEN THEM AND THAT TOM HAS MORE CARDS THAN BILL. WE ALSO KNOW THAT IF YOU MULTIPLIED THE NUMBER OF CARDS TOM HAS BY THE NUMBER BILL HAS THE PRODUCT WOULD EQUAL 135. HOW MANY CARDS DOES TOM HAVE? HOW MANY CARDS DOES BILL HAVE?

RIVER-CROSSING PROBLEM (TRANSFORMATION) - A HEAVY FATHER AND TWO YOUNG SONS HAVE TO CROSS A SWIFT RIVER IN A DEEP WOODS. THEY FIND AN ABANDONED BOAT, WHICH CAN BE ROWED ACROSS, BUT WHICH SINKS IF OVER-LOADED. EACH SON WEIGHS 100 LBS. A DOUBLE-WEIGHT SON IS JUST AS HEAVY AS THE FATHER AND MORE THAN THAT IS TOO MUCH FOR THE BOAT. ASSUMING THAT YOU CANNOT SWIM ACROSS THE RIVER OR HANG ON TO THE SIDE OF THE BOAT AND THAT THE BOAT MUST BE OCCUPIED BY AT LEAST ONE PERSON ON EVERY CROSSING, HOW DO THE FATHER AND THE SONS CROSS THE RIVER?

MATH-RELATIONSHIP PROBLEM - WHICH OF THE FOLLOWING PROBLEMS IS SIMILAR TO THIS PROBLEM IN TERMS OF THE MATHEMATICAL PROCEDURE NEEDED TO SOLVE IT: A FARMER IS COUNTING THE HENS AND RABBITS IN HIS BARN-YARD. HE COUNTS A TOTAL OF 50 HEADS AND 140 FEET. HOW MANY HENS AND RABBITS DOES THE FARMER HAVE?

A) A MOTHER IS 31 YEARS OLD AND HER DAUGHTER IS 13 YEARS OLD. HOW MANY YEARS AGO WAS THE MOTHER EXACTLY 3 TIMES AS OLD AS THE DAUGHTER WAS THEN?

B) BILL HAS A COLLECTION OF 20 COINS THAT CONSISTS ENTIRELY OF DIMES AND QUARTERS. IF THE COLLECTION IS WORTH $4.10, HOW MANY OF EACH KIND OF EACH COIN ARE IN THE COLLECTION?

C) A FARMER IS COUNTING THE HENS AND RABBITS IN HIS BARNYARD. HE COUNTS 6 COOPS WITH 4 HENS EACH, 2 COOPS WITH 3 HENS EACH, 5 CAGES WITH 6 RABBITS EACH, AND 3 CAGES WITH 4 RABBITS EACH. HOW MANY HENS AND RABBITS DOES THE FARMER HAVE?

TABLE 1

(CONT.)

ATTRIBUTE IDENTIFICATION PROBLEM - IMAGINE SOMEONE HAS SORTED A STACK OF INDEX CARDS INTO TWO PILES. EACH CARD CONTAINS EITHER A SQUARE OR TRIANGLE. THE FIGURE MAY BE LARGE OR SMALL AND MAY BE ON THE LEFT OR RIGHT SIDE OF THE CARD. FURTHERMORE, THE AREA INSIDE THE FIGURE MAY BE EITHER BLANK OR HAVE DIAGONAL LINES. THE PERSON PUTS THE CARDS INTO PILE "A" IF THEY MEET A CERTAIN RULE, OTHERWISE THEY WERE PUT INTO PILE "B." LOOKING AT THE CARDS BELOW AND HOW THEY WERE SORTED, DESCRIBE THE RULE FOR PUTTING CARDS INTO PILE "A." (HINT: THE RULE REQUIRES THAT TWO THINGS BE PRESENT FOR THE CARD TO GO INTO PILE "A.")

Table 2

Mean and Standard Deviation Scores for Number of Test Problems Solved

Course		Overall Score	Final Grade in Course					
			A	B	C	D	F	Drop
Introductory	$\bar{X}$	4.51	5.25	4.41	4.35	4.22	4.11	4.37
	SD	1.51	1.22	1.44	1.58	1.56	1.85	1.40
	N	160	32	34	31	9	19	35
Cobol	$\bar{X}$	4.08	5.00	4.83	4.00	0.00	4.00	3.82
	SD	1.54	.82	1.59	1.41	-	-	1.41
	N	60	6	12	2	1	1	38
Advanced	$\bar{X}$	5.26	5.12	5.30	5.33	4.33	6.00	5.50
	SD	1.30	1.22	1.26	1.40	2.08	0.00	1.26
	N	66	17	23	15	3	2	6
Overall	$\bar{X}$	4.59	5.18	4.78	4.65	3.92	4.27	4.19
	SD	1.50	1.20	1.44	1.56	1.93	1.80	1.48
	N	286	55	69	48	13	22	79